Improved species conserving genetic algorithm for solving combinatorial optimisation problems

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Extended Abstract

Niching techniques have been widely investigated in the field of evolutionary computation. With the ability of dividing population into several domains and permitting to explore many peaks in parallel, these methods have become widely used to solve the multimodal optimisation problems with continuous optimisation domain. Every niching method has to simultaneously fulfil two partially conflicting tasks: to find the global optima in the multitude of local peaks and to obtain a set of best solutions for diversity and understandings of the problem. Many different niching concepts and methodologies have been developed. The most prominent examples of such techniques are species conservation [1], clustering [2], fitness sharing [3], crowding [4], clearing [5], restricted tournament selection (RTS) [6], and niching memetic algorithm (NMA) [7].

Nevertheless, despite their properties and abilities, the amount of examples of application of these methods to combinatorial optimisation problems is rather limited. Ikeda and Kobayashi [8] examined a fitness landscapes of the most popular combinatorial optimisation problems, such as job-shop scheduling problem (JSSP) and traveling salesman problem (TSP), and demonstrated that these problems typically have a *deceptive multimodal landscape* (i.e. strong local optima exist far from the global optima). Moreover, the authors showed that the fitness landscape of these problems has a structure of a *big valley* [9], meaning that one area of the solution space might contain many solution candidates that tend to be very similar to each other. Depending on the problem instance, its fitness landscape might consist of several big valleys. Ikeda and Kobayashi [8] suggested that search for a global optima in these problems is more difficult for the following reasons: a globally multimodal search space, and a *UV-structure* of the fitness landscape.

Moreover, Czogalla and Fink [10] independently analysed a fitness landscape of the resource-constrained project scheduling problem (RCPSP) and provided a statistical analysis of their research. The authors proved that the solution space of the RCPSP, similarly to other combinatorial optimisation problems, also has a big valley structure. Further, they showed that good solutions tend to be close to other good solutions (but not too close) and they are spread all around the solution search space. The statistical analysis indicated that the landscape of the RCPSP is filled with relatively high amount of *interior plateau* meaning that for one problem there might be several global solutions.

From the above-mentioned works, it can be concluded that a globally multimodal landscape of these problems consists of plural big valleys, and of each of them has its own important local or global optima. In the optimisation point of view, it is highly desirable to locate multiple optima for at least two reasons. Firstly, focusing on finding multiple optima will help to maintain a diversity in the population, thus will reduce chances of falling into local optima trap and increase chances of finding a global solution. Secondly, identifying diverse set of high quality solutions can provide an alternative, potentially better and more innovative, outcome result.

When adapting any niching technique to combinatorial optimisation problem, there is a number of issues to consider: 1) solution representation scheme specific for the problem; 2) metrics for estimation of a similarity between individuals based on the chosen solution representation scheme; 3) perturbation and movement operators.

☆This research work was partially supported by the Innovate UK funded project HARNet Agreement No. CA/HRNT/03/2014

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This paper presents a continuation of work that was started by Li et al. [11] and provides an improved version of species conserving genetic algorithm (SCGA) that was adapted for solving RCPSP, which have been demonstrated to be NP-hard combinatorial optimisation problem with a wide solution search space containing large amount of local and global optima.

The original SCGA relies on a species conservation technique in obtaining multiple global solutions. This technique is based on distributed elitism, achieved by identifying in each generation a set of prime individuals that are considered to be worth preserving into the next generation. By running tests on various multimodal optimisation problems from the literature, Li et al. [1] were able to demonstrate that with the application of species conservation, they were able to reliably find all the global optima for all problems, as well as achieve competitive performance of their algorithms. The improved SCGA (ISCGA), presented in this paper, introduces several new changes to original paradigm: a new representation of a solution specific for RCPSPs, novel mutation and crossover operators, and new means of estimating similarity between individuals.

The performance of proposed ISCGA is tested against a set of universal benchmark instances for RCPSPs from the well-known PSPLIB [12] library and compared against other state-of-the-art methodologies to confirm the effectiveness of the proposed method. By managing to obtain a set of global solutions for each of the benchmark instances, ISCGA confirmed multimodal properties of the RCPSP and suitability of such methods for application to combinatorial optimisation problems. Moreover, comparison of computational results with other state-of-the-art methodologies for the RCPSP showed the competitiveness of the proposed method.

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